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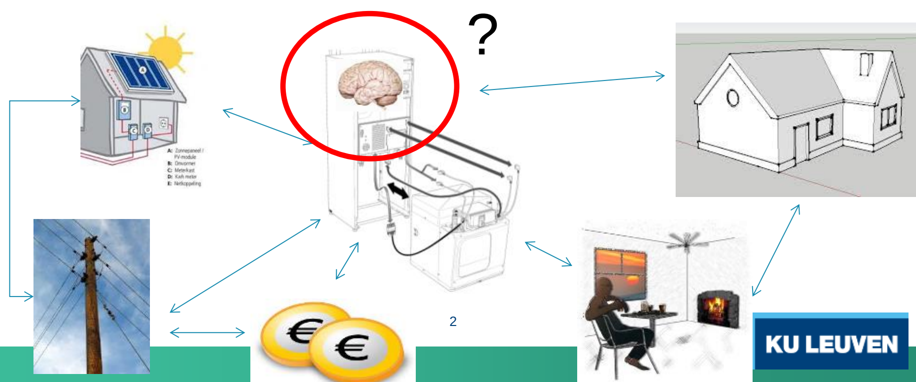
# Warmtepompen bufferen elektriciteit als warmte

**Smart Grid School, 8 oktober 2013**

**Dr. ir. Maarten Sourbron**
Campus De Nayer
Departement Industriële Ingenieurswetenschappen,
KU Leuven

## Wat?

Slimme sturing van warmtepompen =
Aan/uit-schakeling i.f.v externe signalen
(bijvoorbeeld dynamische tarieven)

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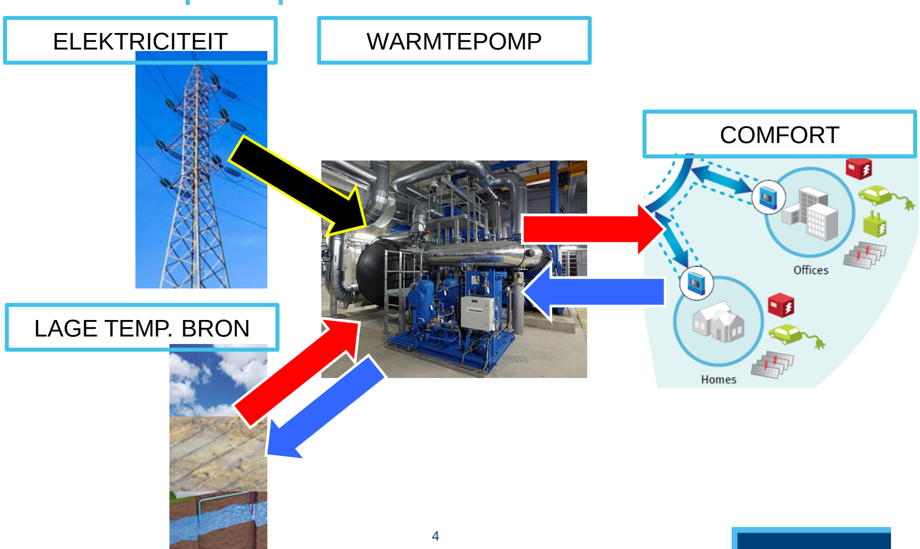
# Waarom?

Optimaal gebruik van hernieuwbare energie
(afstemmen aanbod-vraag)

Vermijden piekbelasting E-net



# Warmtepomp: elektriciteit → warmte

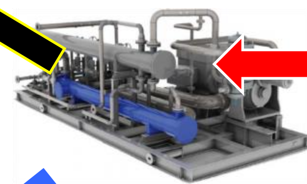


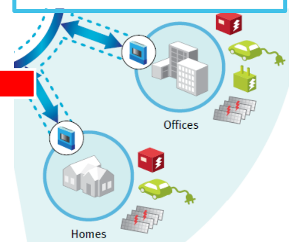
# Warmtepomp: warmte → elektriciteit?

ELEKTRICITEIT

WARMTEPOMP

AFVALWARMTE





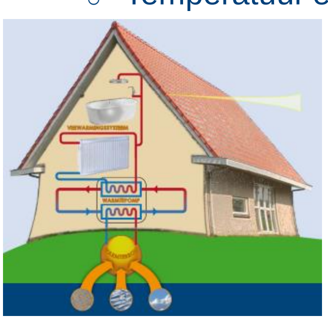

LAGE TEMP. BRON

Hoge temperatuur afvalwarmte (>80°C): $\eta_{max}$ = 24%



# Werking van een warmtepomp

- 3 fysische verschijnselen
  - Warmte bestaat op verschillende temperatuur
  - Verdamping van een vloeistof ➔ warmte in
    Condensatie van een vloeistof ➔ warmte uit
  - Temperatuur en kookpunt stijgen als druk stijgt



# (1) Warmte op verschillende temperatuur

1 ton water

- Van 10°C naar 0°C: 11,4 kWh
- Van 70°C naar 60°C: 11,7 kWh

Bij warmte hoort een temperatuurniveau!

Hogere temperatuur = nuttiger!

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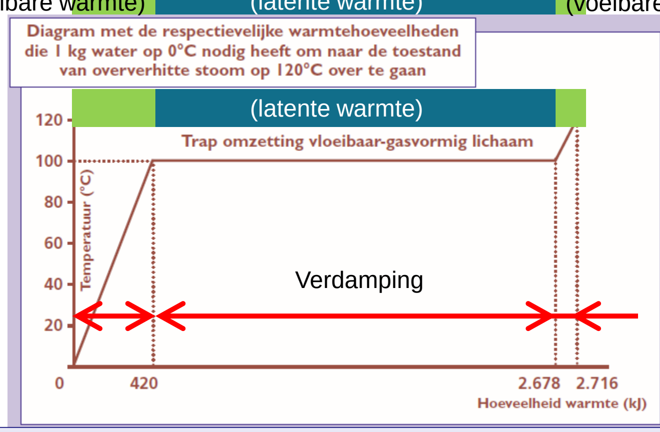
# (2) Verdampingswarmte

(voelbare warmte) (latente warmte) (voelbare warmte)




[1]

1ton water op 0°C verdampen (bij 0,006bar): 695 kWh
1ton water op 100°C verdampen (bij 1,014bar): 743 kWh

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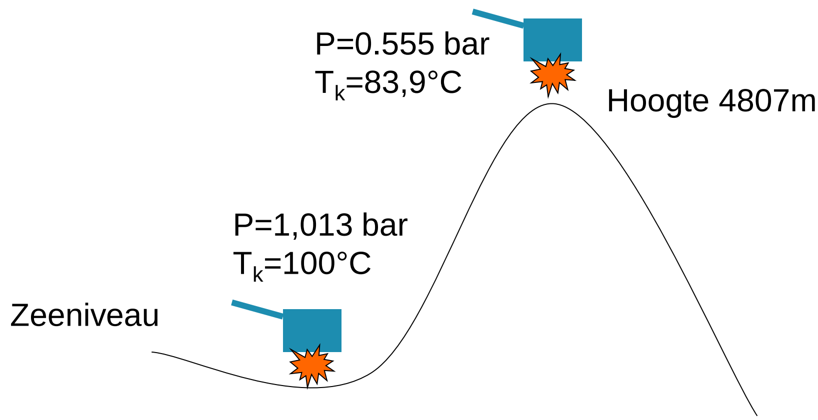
## (3) Kookpunt = functie(druk)

- Het ‘Mont Blanc’ voorbeeld






## (3) Kookpunt = functie(druk)

- Typische warmtepomp-vloeistoffen: ‘koudemiddel’

| Koudemiddel | Kookpunt 0°C | Kookpunt 40°C |
|---|---|---|
| R-134a | 2,9 bar | 10,2 bar |
| R410a | 8,2 bar | 24,0 bar |
| R-290 (propaan) | 4,7 bar | 13,7 bar |

## Werking van een warmtepomp

| | | |
|---|---|---|
| Warmte op hoge temperatuur | bv. 35°C | Wel bruikbaar |
| Warmte op lage temperatuur | bv. 5°C | Niet bruikbaar |

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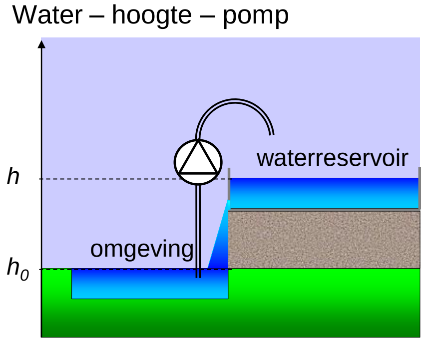
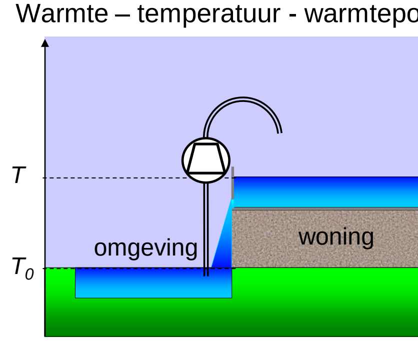
## Werking van een warmtepomp

Analogie: water - warmte

Water – hoogte – pomp




Warmte – temperatuur - warmtepomp

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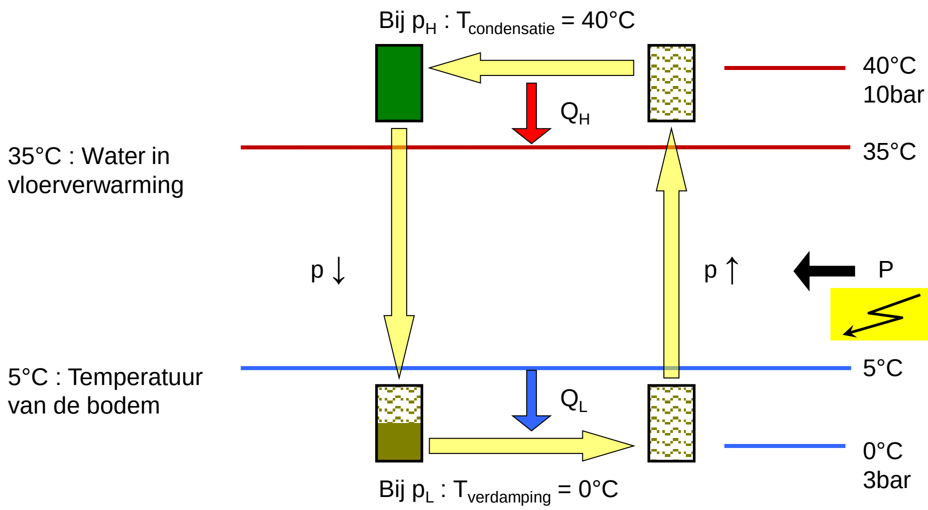
# Werking van een warmtepomp






# Werking van een warmtepomp

- **PRESTATIEFACTOREN**
- **COP** (Coefficient Of Performance)
  - ogenblikkelijk
  - eigenschap van het toestel
  - (vgl. verbrandingsrendement van ketel)
  - *(bepaald in testlabo)*
- **SPF** (Seasonal Performance Factor)
  - over periode
  - eigenschap van de installatie
  - (vgl. seizoensrendement van ketel-installatie)
- **PER** (Primary Enery Ratio)
  - Primair energieverbruik
  - eigenschap van de installatie

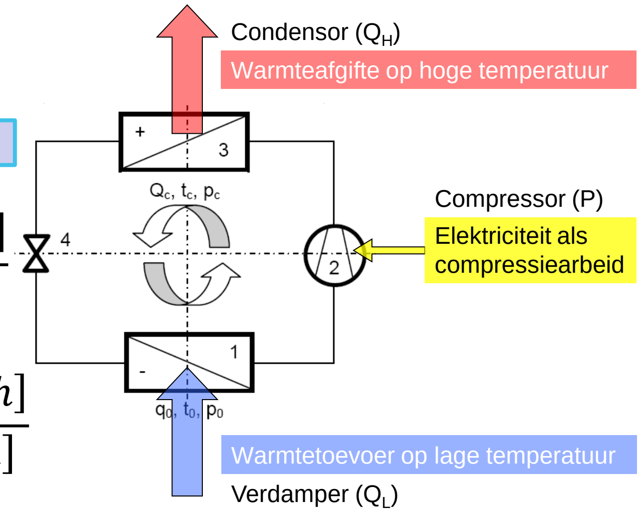
# Werking van een warmtepomp

$$Q_H = Q_L + P$$

$$\boxed{4 = 3 + 1}$$

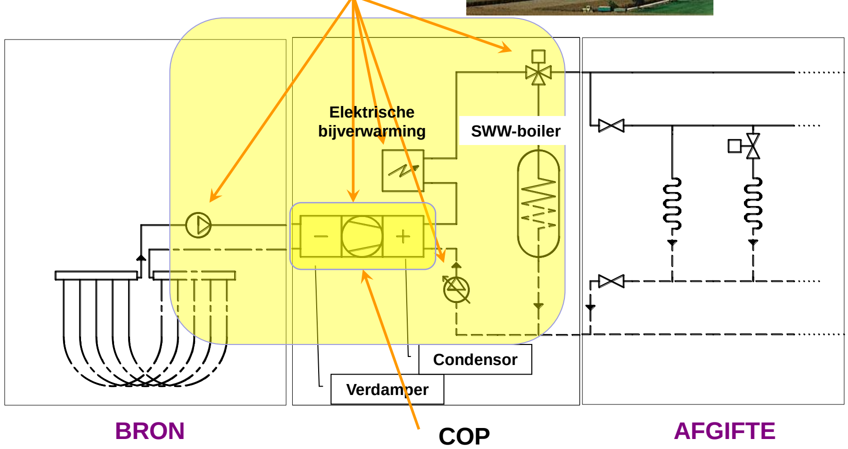
$$COP = \frac{\dot{Q}_H\,[W]}{\dot{P}\,[W]}$$

$$SPF = \frac{Q_H\,[kWh]}{P\,[kWh]}$$



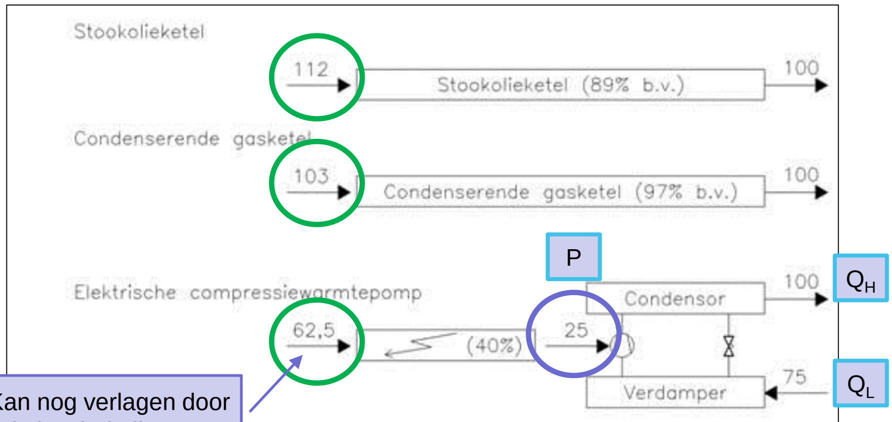



# Werking van een warmtepomp



# Smart grids en warmtepompen

- Elektrificatie van verwarming en koeling




Kan nog verlagen door de inschakeling van hernieuwbare energie

[5]



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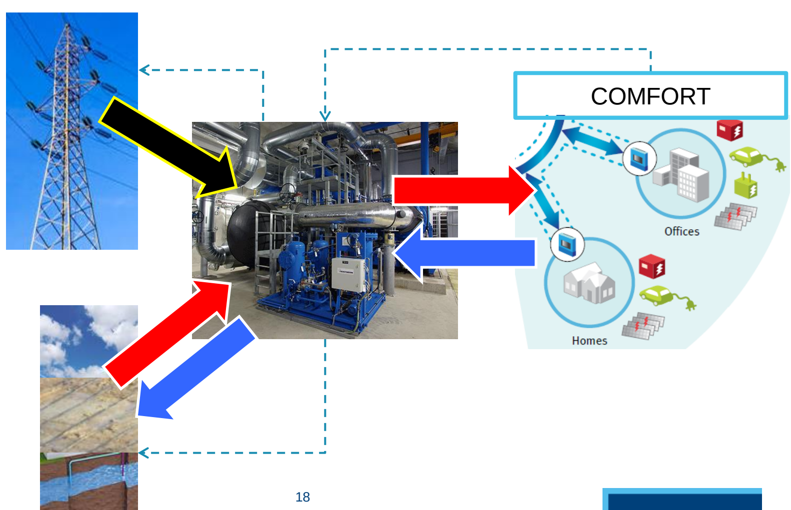
# Warmtepomp: vraaggedreven



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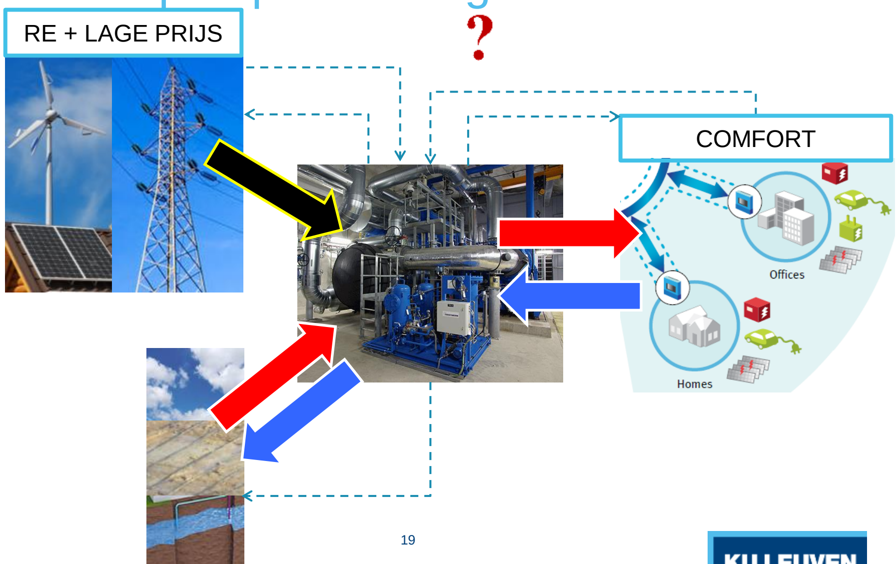
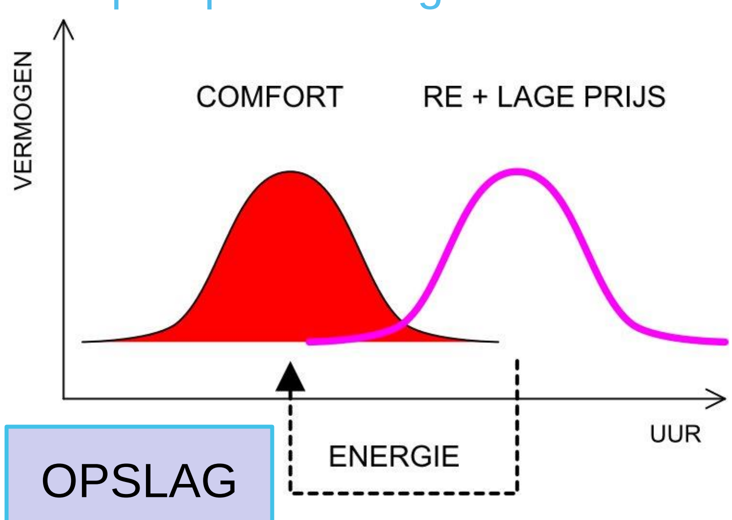
# Warmtepomp: aanbodgedreven?

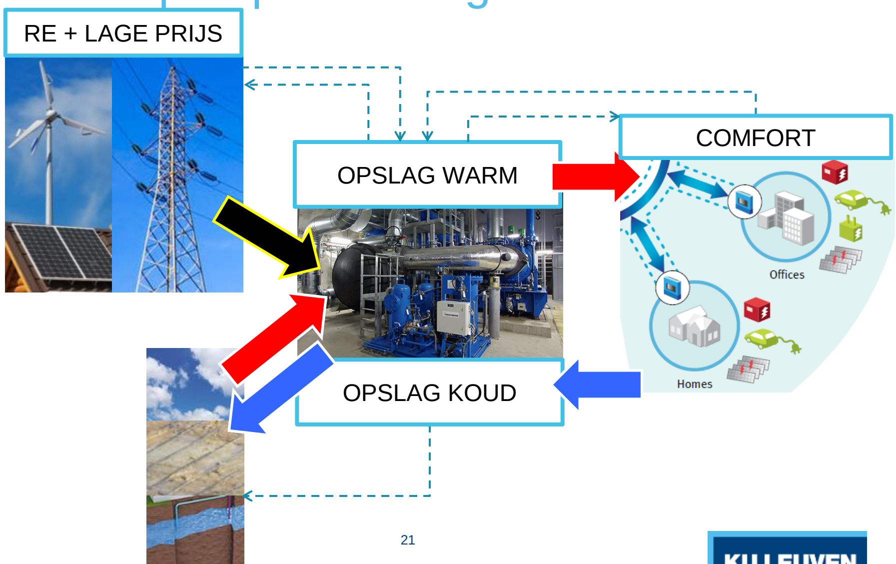





# Warmtepomp: aanbodgedreven?



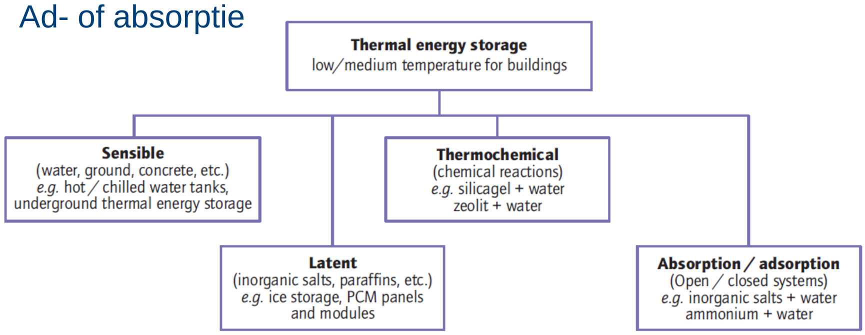
# Warmtepomp: aanbodgedreven?






# Types van thermische opslag

- Voelbaar: Water, gebouwmassa, ...
- Latent: fase-verandering
- Thermo-chemisch
- Ad- of absorptie



# Types van thermische opslag

**Table 6: Energy capacities, power, efficiency and storage time of thermal energy storage technologies**

| TES technology | Capacity kWh/t | Power kW | Efficiency (%) | Storage time | Cost (USD/kWh) |
|---|---|---|---|---|---|
| Hot water tank | 20-80 | 1-10 000 | 50-90 | day-year | 0.1-0.13 |
| Chilled water tank | 10-20 | 1-2 000 | 70-90 | hour-week | 0.1-0.13 |
| ATES low temp. | 5-10 | 500-10 000 | 50-90 | day-year | Varies |
| BTES low temp. | 5-30 | 100-5 000 | 50-90 | day-year | Varies |
| PCM-general | 50-150 | 1-1 000 | 75-90 | hour-week | 13-65 |
| Ice storage tank | 100 | 100-1 000 | 80-90 | hour-week | 6-20 |
| Thermal-chemical | 120-150 | 10-1 000 | 75-100 | hour-day | 10-52 |

Source: ECES and Roth, K. Zogg, R. and Brodrick, J. (2006).
Note: ATES stands for aquifer thermal energy storage and BTES stands for borehole thermal energy storage.

[3]





# Types van thermische opslag

Table 1. Comparison of various heat storage media (stored energy = $10^6$ kJ = 300 kWh; $\Delta T$ = 15 K)

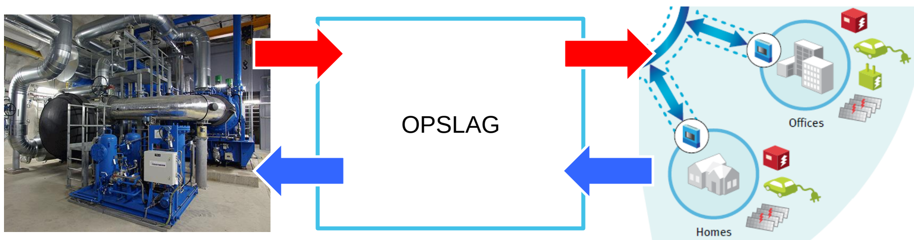
| | Heat Storage Material | | | |
|---|---|---|---|---|
| | Sensible heat storage | | Phase Change Materials | |
| Property | Rock | Water | Organic | Inorganic |
| Latent heat of fusion (kJ/kg) | * | * | 190 | 230 |
| Specific heat (kJ/kg) | 1.0 | 4.2 | 2.0 | 2.0 |
| Density (kg/m$^3$) | 2240 | 1000 | 800 | 1600 |
| Storage mass for storing $10^6$ kJ (kg) | 67000 | 16000 | 5300 | 4350 |
| Relative mass** | 15 | 4 | 1.25 | 1.0 |
| Storage volume for storing $10^6$ kJ (m$^3$) | 30 | 16 | 6.6 | 2.7 |
| Relative volume** | 11 | 6 | 2.5 | 1.0 |

*Latent heat of fusion is not of interest for sensible heat storage.
**Relative mass and volume are based on latent heat storage in inorganic phase change materials

[4]

# Thermische opslag: vereisten

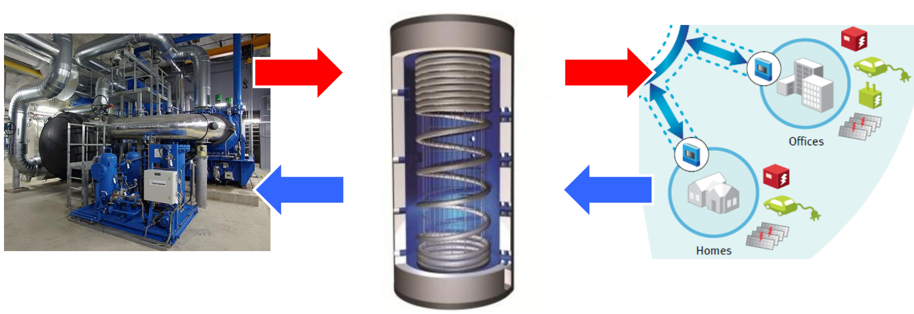
- Hoge en regelbare vermogenuitwisseling in en uit!





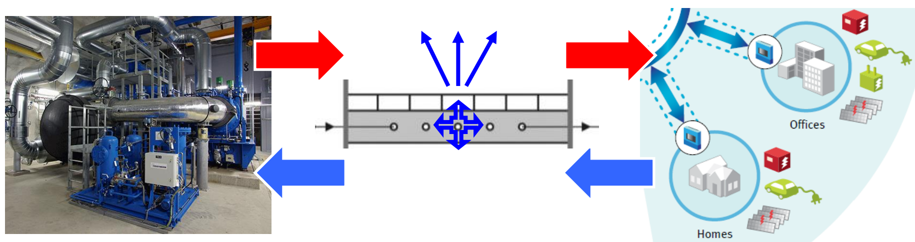

# Thermische opslag: vereisten

- Hoge en regelbare vermogenuitwisseling in en uit!
  - Voelbare warmte: water ➔ OK



## Thermische opslag: vereisten

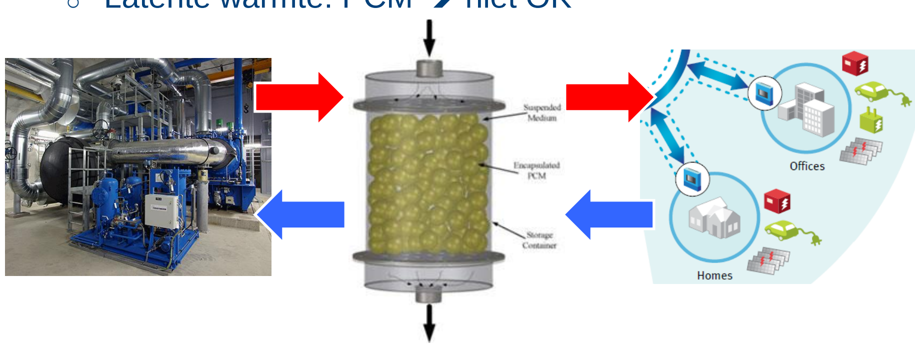
- Hoge en regelbare vermogenuitwisseling in en uit!
  - Voelbare warmte: beton ➔ niet OK



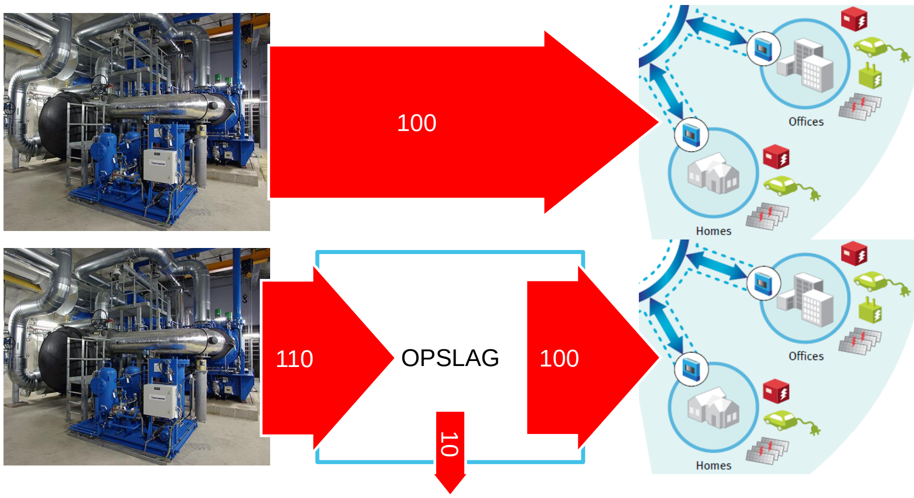



## Thermische opslag: vereisten

- Hoge en regelbare vermogenuitwisseling in en uit!
  - Latente warmte: PCM ➔ niet OK



# Thermische opslag = regelverlies

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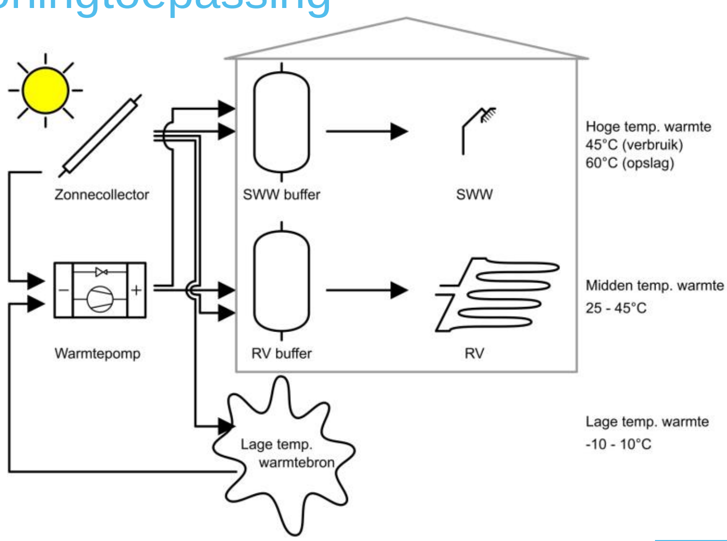
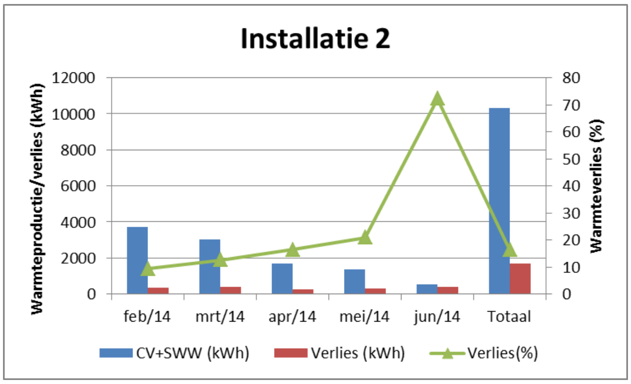
# Woningtoepassing

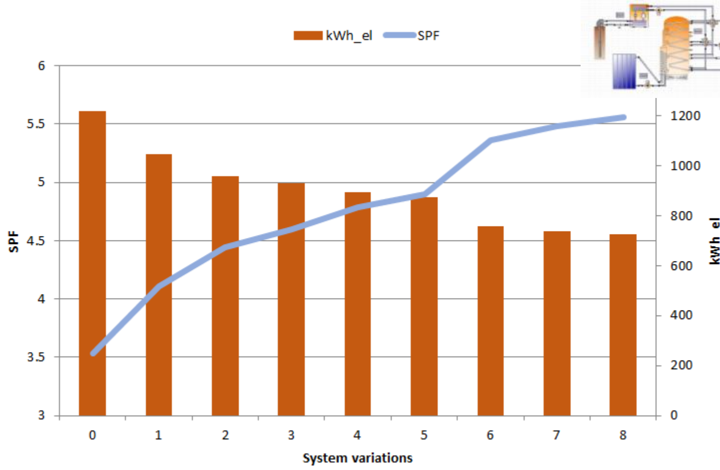


# Warmteverlies buffer: voorbeeld

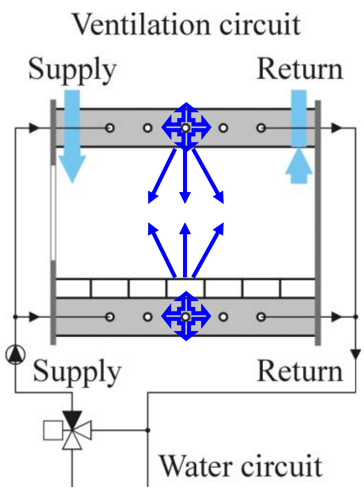



Uit: IWT-TETRA Zonwarm (http://zon-warm.lessius.eu/)

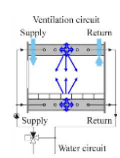
# Hydraulische aansluitingen en regeling




# Warmtepomp en betonkernactivering




# Warmtepomp en betonkernactivering




- Voorbeeld...

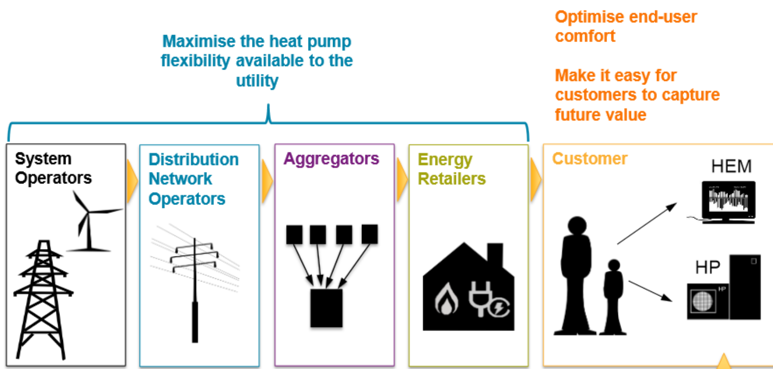
| | | |
|---|---|---|
| **Gebouw** | 5000 | m² |
| **Opslagcapaciteit BKA (120 W/m²)** | 0.15 | kWh/m² thermische energie WP bij stap 20-30°C (looptijd 1u) |
| **Elektrisch verbruik WP (SPF=4)** | 0.0375 | kWh/m² elektrisch verbruik WP bij stap 20-30°C (looptijd 1u) |
| **Zonder directe impact op comfort** | 37.5 | W_e/m² @ 1 kwartier (per m²) |
| | 188 | kW_e @ 1 kwartier (volledig gebouw) |
| | 47 | kWh_e/kwartier |
| **Stel: 1 keer per dag** | 17109 | kWh_e/jaar |
| **prijs** | 0.1 | €/kWh |
| **@elek-prijs ????** | 1711 | €/jaar |

- Als ΔT-marge in BKA...

# Warmtepomp en smart grids

**Why energy companies will need smart heat pumps - What does it means for the heat pump industry?**

DELTA Energy & Environment




**With customers on board, smart will be a significant driver of the future heat pump market**



# Warmtepomp en smart grids

**European smart heat activity: Different approaches to capturing flexibility & creating customer propositions**

DELTA Energy & Environment

# Warmtepomp en smart grids

**How much value could come to the customer? Many don't agree!**

DELTA Energy & Environment

Quotes from studies, reports and research calls:

"The value of flexibility from a dishwasher is £3 today; by 2025 it will be more than £100" *Professor Goran Strbac, Imperial College, London*

"Real time optimisation gives better cost benefits to the end-user" *TNO*

"We can save as high as 10-20% of the variable part of the bill, so 5-10% on the total bill" *Trial of smart heat pumps in Scandinavia*

"The real value to the customer – and to the utility – will come through automated response" *HEM company*

"Save up to 15% with Fortum Fiksu dual fuel" *Fortum*

"2020 and 2030 cost savings of €25-€40 per year from a smart heat pump" in Germany *Ecofys study, Germany*

"Sophisticated control of heat pumps" is key *Danish smart grid contact*

"ToU tariffs give customers cheaper bills overall - but have had little impact on HP demand patterns…" *British Gas*

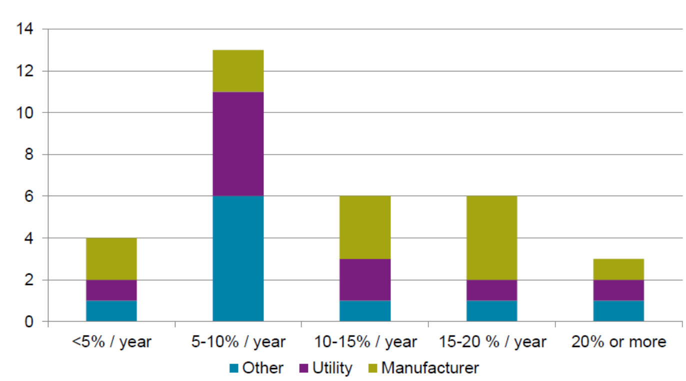


# Warmtepomp en smart grids

**Industry Survey from Delta-ee/EHPA HPs Roundtable: How much value could come to the customer?**

DELTA Energy & Environment

In 2020, 'smart' operation of heat pumps (i.e. changing the operating times in response to e.g. dynamic tariffs) will give end-users X% savings on their annual electricity bills (where savings are relative to 'normal' operation of the heat pump.



# Warmtepomp en smart grids

Heat pumps, combined heat & power and cooling installations could play an important role in smart electricity grids if thermal production can be decoupled from thermal demand. [2]

There is a need to develop, in line with Smart-Grid / Smart-Homes technologies, methods to accurately determine the state of charge, controls and control algorithms so that heating and cooling is optimally generated from the RES (e.g. night time excess wind energy / PV) when available, while still providing the consumer with their needs at a time of their choosing. [2]

The establishment of an open source communication protocol for Smart Grids / Smart Homes would enable manufacturers to create and commercialise devices that are compatible with many systems. [2]

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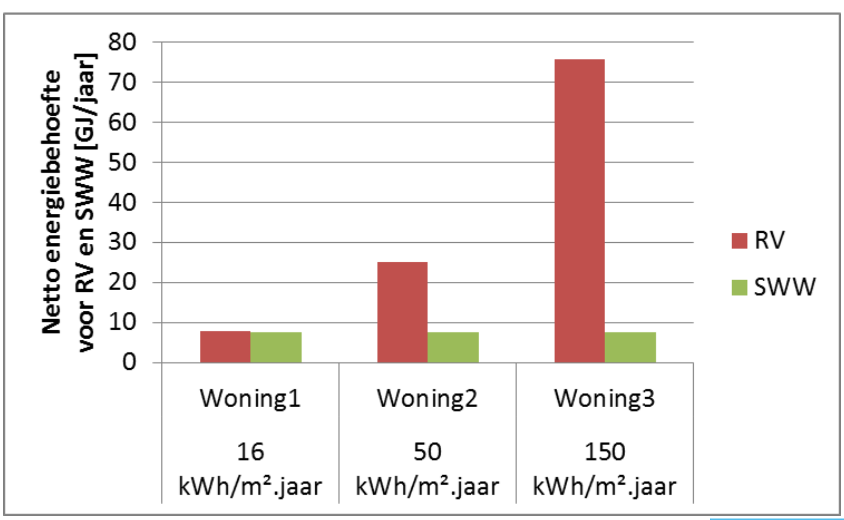
# Doel van een warmtepomp?



## Warmtepomp en smart grids

- Opportuniteiten in combinatie met thermische opslag
  - Elektrische verwarming en koeling
  - Regelbare elektrische verbruiker (zie eig. opslag)
- Dubbele functie: waardeverhoging
  - Dienst aan gebruiker: comfort
  - Dienst aan elektriciteitsnet: balancering

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# Dank u wel!

Maarten Sourbron, *Warmtepompen bufferen elektriciteit als warmte*, Smart Grid School (Smart Grid Flanders), 8 oktober 2014

# Bronnen

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